

## The multiple periods and the magnetic nature of CP Pup

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**Abstract.** Fast cadence time resolved spectra taken at the CTIO-4 m telescope with the RC-spectrograph during 2 consecutive nights revealed a long term modulation of the binary radial velocity. Chandra hard X-ray spectra taken with the HETGS instrument showed features typically observed in magnetic white dwarfs (WD). Here, we present the new data and suggest that CP Pup is possibly a long orbital period intermediate polar.

### 1. Introduction

CP Pup has been one of the fastest and brightest novae ever recorded. It reached  $V_{max}=0.2$  mag in Nov 1942 and declined by several mag in less than 1 week ( $t_3=6.5$  days). After outburst it has not returned to the quiescent level it had before outburst, remaining about 5 mag brighter (Schaefer & Collazzi 2010).

The post outburst quiescent phase has been studied through time resolved broad band imaging and spectroscopy (Barrera & Vogt 1989, Bianchini et al. 1985, 2012, Cropper 1986, Diaz & Steiner 1991, Duerbeck et al. 1987, O'Donogue et al. 1989, Patterson & Warner 1998, Szkody & Feinswog 1988, Warner 1985, White et al. 1993) suggesting that CP Pup is a short orbital period Cataclysmic Variable (CV). The spectroscopic period is shorter than the photometric period and both periods are unstable/variable. The WD mass derived from radial velocity studies has always been too small ( $<0.2$  to  $<0.6 M_{\odot}$ ) to be consistent with classical nova theory and stellar evolution time scales. X-ray observations (Balman et al. 1995, Orio et al. 2009) have always suggested a possible magnetic nature of the primary WD, though they could never firmly establish it.

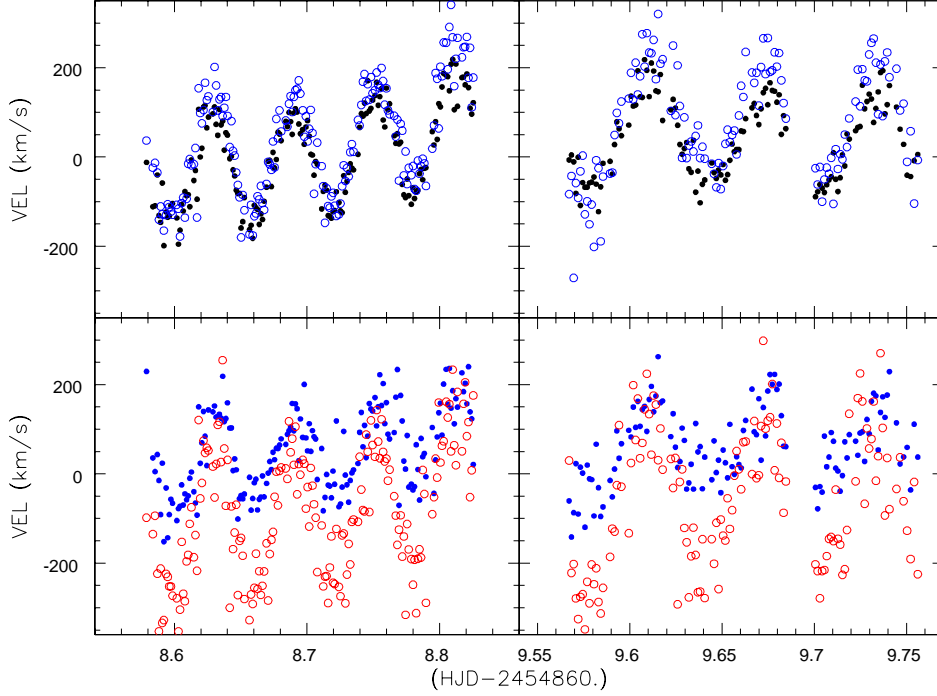


Figure 1. CP Pup radial velocities observed during the nights Feb 6 (left panels) and Feb 7 (right panels), 2009. H $\beta$  (black symbols) and H $\gamma$  (blue circles) radial velocities are shown in the top panels; while the He II (blue symbols) and C III (red circles) lines are shown in the bottom panels.

## 2. Optical observations and results

Time resolved spectra were collected at the CTIO 4m telescope equipped with the RC-spectrograph on Feb 6 and 7 2009. The wavelength coverage was 3500-6000 Å with a resolution FWHM~6 Å. The exposure times were 60 s each with a duty cycle of less than 2 min.

The radial velocity measures of the H $\beta$ , H $\gamma$ , He II  $\lambda$ 4686 and C III(1), show a drift of the data points during the first night and possibly an offset from night to night (Fig. 1). From the Fourier analysis of the whole data set we find two periods (Fig. 2): 1) the well known ~1.47 hr period (up to now interpreted as the orbital period of the binary), and 2) a longer period of ~10 hr. This period is highly uncertain but possibly matches the true orbital period of the system.

## 3. X-ray observations and results

High resolution X-ray spectra were taken with Chandra and the HETGS spectrograph. The wavelength coverage was 0.410 keV at a resolution of  $E/\Delta E \sim 1000$ . Seven exposures were collected between September 30 and October 31 2009 for a 175780 s of total integration time.

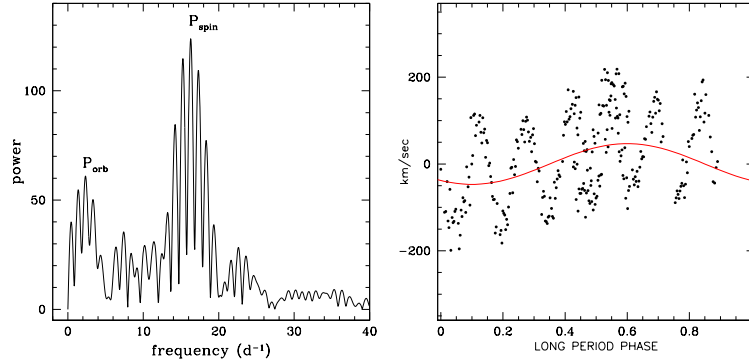


Figure 2. Left panel: Power spectrum of the 2 nights H $\beta$  radial velocities. Right panel: radial velocity curve of the H $\beta$  emission line phased on the long period of  $\sim 9.77$  hr and best fit (red line).

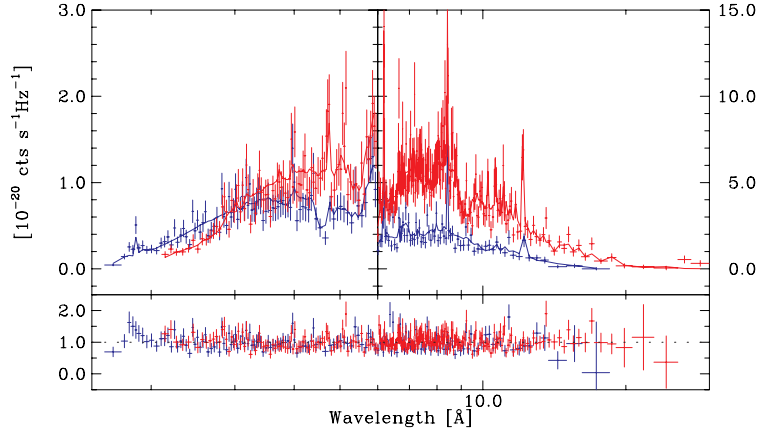


Figure 3. Upper panels: data and model in logarithmic (blue) wavelength and linear (red) count rate scale. Note that we split the plot in two at 6 Å and used different Y scalings. Lower panel show the data/model ratio.

Our new Chandra observations – though limited by a relatively low signal-to-noise ratio – show that the X-ray spectrum of CPPup is modified by a complex, intrinsic absorber. While this is commonly seen in magnetic CVs, it has not been seen in non-magnetic CVs except at very high inclination angle (i.e., systems showing at least a grazing eclipse; see Mukai et al. 2009). This supports the magnetic CV interpretation. Within this hypothesis and following Mukai et al. (2003) we fit the spectra using a cooling flow model. Our best fit model temperature is  $kT=36.5$  keV with a 90% confidence range of 20.2-55.7 keV. Our best fit temperature corresponds to a WD mass of 0.8 (0.57-0.99)  $M_{\odot}$ . Such a WD mass is in much better agreement with the current classical nova theory, though still on the low end of its expected value.

#### 4. Conclusion: CP Pup as a long period intermediate polar

Our new optical and X-ray data suggest that CP Pup is a magnetic CV, most likely of the intermediate polar (IP) type. In particular, the longer term modulation of the radial velocity curve suggests that CP Pup is not a short orbital period system but a long period CV with orbital period  $P \gtrsim 10$  hr. Should this be confirmed, the spectroscopic period of  $\sim 1.47$  hr should be interpreted as the WD spin and its instability as an effect induced by the varying geometry of the emitting region (i.e. the accretion curtain magnetic field lines that are continuously stretching, breaking and reconnecting). The slightly longer photometric period, instead, should be regarded as the beat between the spin and the orbital period. Unfortunately, due to the range of values recorded for both the spectroscopic and photometric period and due to the lack of simultaneous spectroscopic and photometric observations, we could not constrain the putative long orbital period through simple beat frequency calculations. In addition, should CP Pup be a long orbital period IP, the observed X-ray modulation (Orio et al. 2009, Balman et al. 1995) would arise from the accreting magnetic pole(s) and match the WD spin period; the NIR light curve (Szkody & Feinswog 1988) should be interpreted similarly to DQ Her (Chanan & Nelson 1978), and the calculation of the dynamical masses would certainly deliver more reasonable values, possibly consistent with those determined from the X-ray observations. However, as the longer period is poorly sampled and highly uncertain, it remains necessary to observe CP Pup again, in time resolved spectroscopy and over at least four consecutive nights, thus to securely pin down the long period existence and its exact value.

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